Nguyen Duy Hoa
Global Technical Director
Empyreal Products, Cargill Inc.
Vietnam
Email: Duyhoa_nguyen@cargill.com

Fishmeal Alternatives and Formulation Approaches

Abstract

Fishmeal alternatives for F3 (Fish Free Feed) is a friendly environmental & sustainable approach for aquaculture feed industry. However, there are several challenges in the innovation of fishmeal alternatives in terms of quality consistency, quantity availability, especially nutritional limitations as well as cost effectiveness of fishmeal replacement.

This presentation will review the trends in fishmeal usage and replacement, challenges of nutritional limitations, and recommendations for the formulation approaches of the fishmeal alternatives to different species, focusing on carnivorous fish and shrimp.

FISHMEAL ALTERNATIVES & FORMULATION APPROCHES

Nguyen Duy Hoa, PhD.
Global Technical Director, Cargill Inc.
www.motivshrimp.com

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Agenda

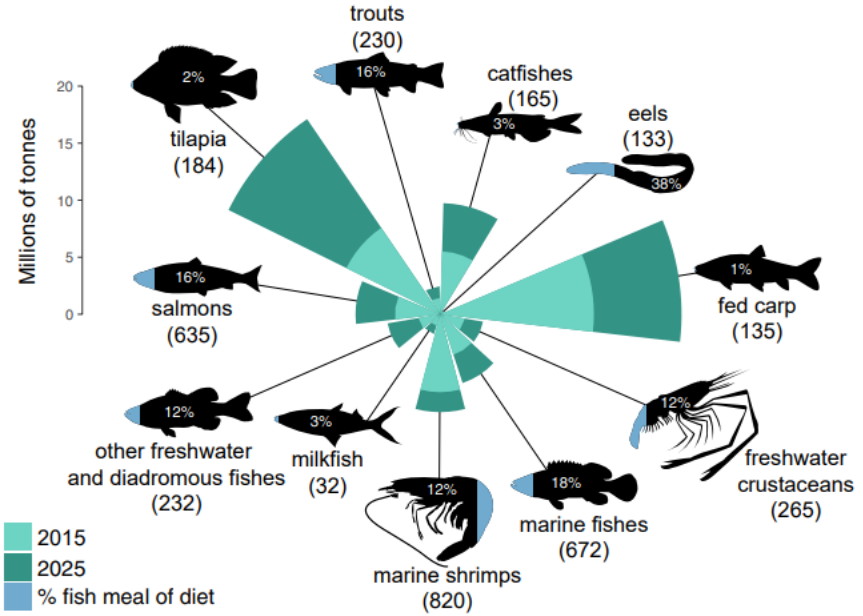
- Trend of fishmeal usages
- Challenges of fishmeal alternatives
- Formulation approaches for fishmeal replacement
- Take-home messages

Trends of fishmeal usages

Use of fishmeal by agriculture – The fishsite.com

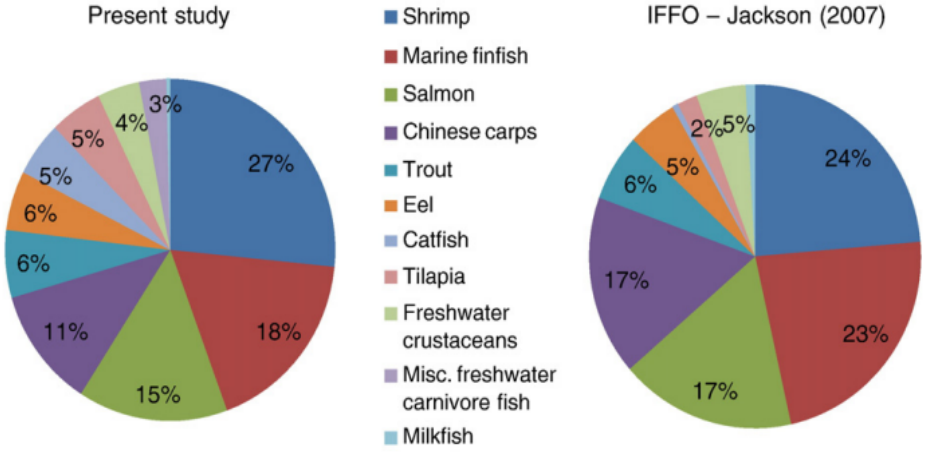
Sector	2002 Year 2010	
Aquaculture	46%	56%
Pigs	24%	20%
Poultry	22%	12%
Ruminants	1%	<1%
Other	7%	12%

6.0-6.5 million MT of fishmeal produced annually



(Katheline, et al., 2019)

Trends of fishmeal usages



Estimated global use of fish meal within compound aquafeeds in 2006 from the present study and from IFFO estimations (values given as percent total aquafeeds; Jackson 2007) - Albert G.J. Tacon a, *, Marc Metian (2008)

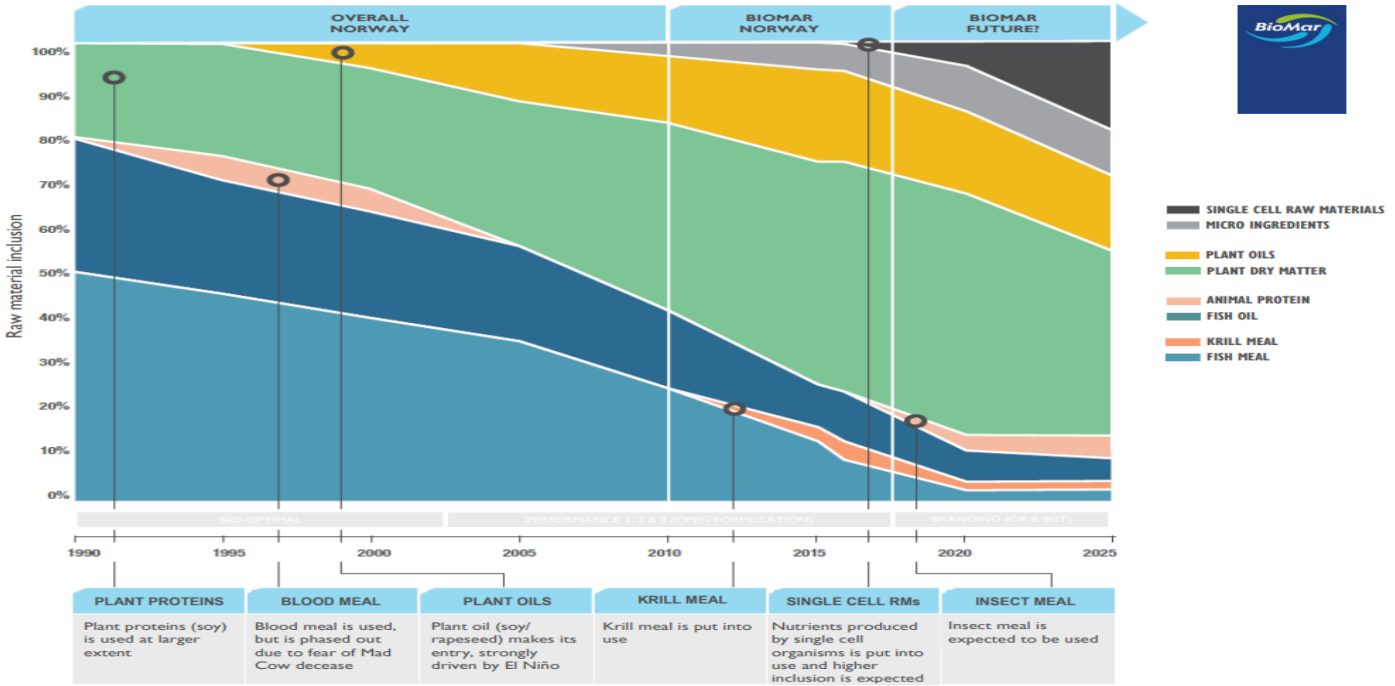
	2020		2021		2022	
	Volume (tons)	Value (mill USD)	Volume (tons)	Value (mill USD)	Volume (tons)	Value (mill USD)
 5-7% GAGR	4,093,000	28,450	4,600,000	33,810	5,050,000	37,300
 4% GAGR	3,200,000	20,240	3,300,000	20,880	3,460,000	21,900

- *Shrimp contribute 10.1% of global seafood supply (2019)*
- *Salmonid contribute 4.6% of global seafood supply (2019)*

(Vinij Tansakul, 2022)

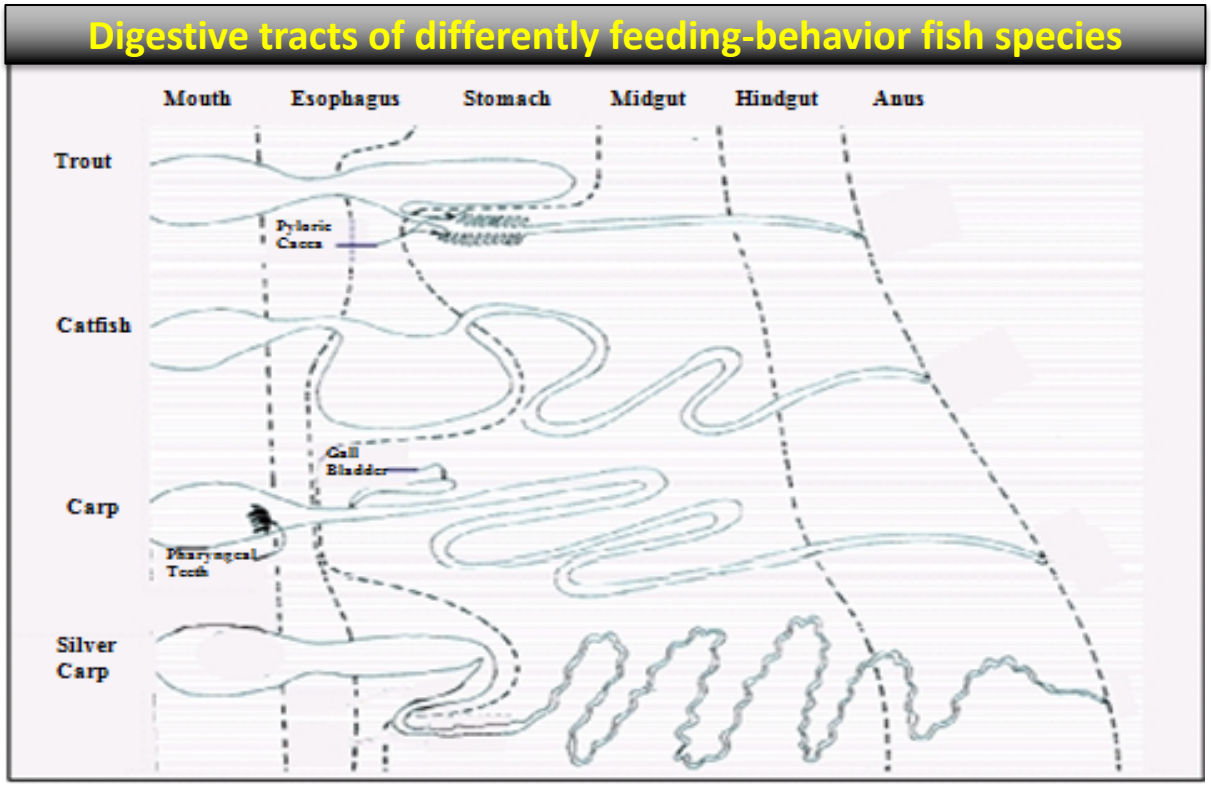
Trends of fishmeal usages

Salmon feed has evolved over time



Vidar Gundersen, Global Sustainability Director, Biomar, 2019 – APA 2019 in Chennai – India.

Trends of fishmeal usages



Herbivores: feeding on plant materials
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Omnivores: feeding on mixed diets
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Detritivores: feeding on detritus
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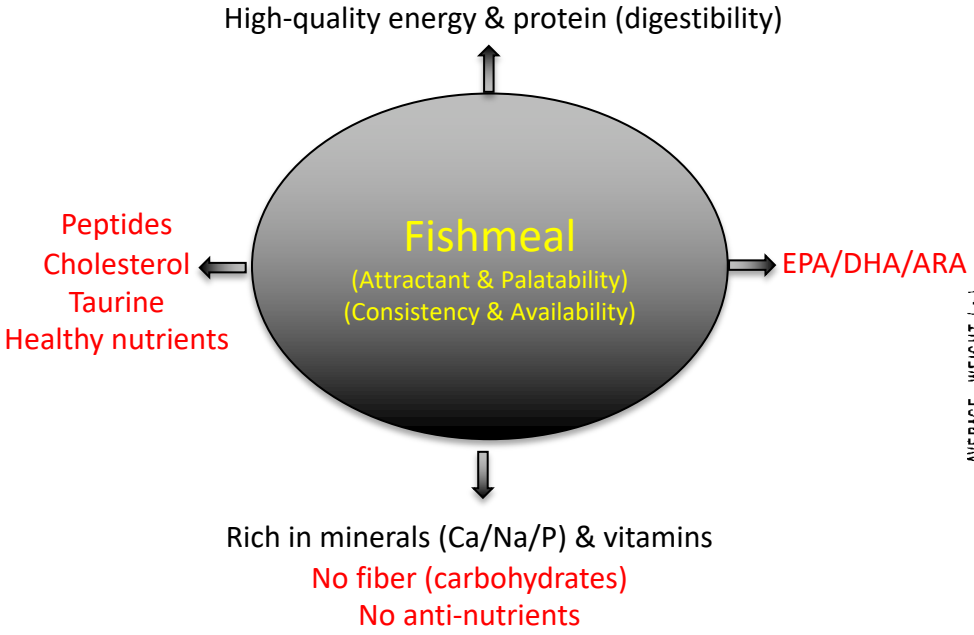
Carnivores: feeding on fish & other invertebrates.

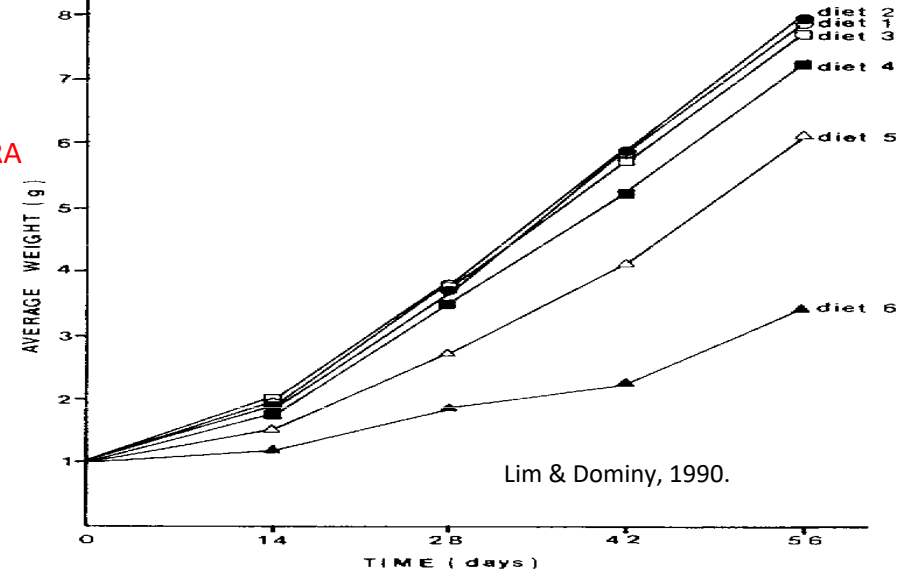
Marine fish is Carnivorous species

Challenges of fishmeal alternatives

Why Fishmeal is good protein source



Ingredients and nutrient content	Diet number					
	1	2	3	4	5	6
Ingredients						
Animal protein mix[1]	53.30	42.70	32.00	21.30	10.70	–
Soybean meal	–	14.00	28.00	42.00	56.00	70.00
High gluten wheat flour	10.00	10.00	10.00	10.00	10.00	10.00



Lim & Dominy, 1990.

Challenges of fishmeal alternatives

High-quality fishmeal

Made up of single fish species
High protein level (minimum 65% protein)
High freshness
High digestibility
Low contaminants (heavy metals, etc.)

Low-quality fishmeal has been used mainly in freshwater fish species while high-quality fishmeal has been used mainly in shrimp and marine fish species.

Ready to pay 700 – 1,000 usd/MT higher for high-quality FM than low-quality FM

	Unit	PBM[a]	FM[b]	SBM[c]
Dry Matter (DM)	% as fed	93.7 (82.4–97.4)	92.1 (90.0–94.4)	87.9 (85.0–92.1)
Crude protein	% DM	66.1 (51.6–81.0)	75.6 (70.2–80.7)	51.4 (48.3–54.5)
Lysine	% protein	4.4 (3.3–8.2)	6.1 (5.5–7.5)	6.1 (5.7–6.6)
Methionine	% protein	1.4 (1.0–2.0)	2.2 (2.0–2.6)	1.4 (1.2–1.6)
Methionine + Cystine	% protein	–	2.9 (2.6–3.2)	2.9 (2.5–3.3)
Tryptophan	% protein	0.5 (0–0.8)	0.8 (0.7–0.9)	1.3 (1.2–1.4)
Threonine	% protein	2.8 (1.9–3.9)	3.1 (2.9–4.3)	3.9 (3.5–4.3)
Leucine	% protein	5.0 (3.9–9.7)	5.9 (5.2–7.3)	7.5 (6.8–8.0)
Isoleucine	% protein	2.7 (1.8–4.7)	3.7 (3.3–4.4)	4.6 (4.3–5.0)
Valine	% protein	3.1 (2.2–5.2)	4.2 (3.9–4.8)	4.8 (4.3–5.4)
Histidine	% protein	1.9 (1.2–5.6)	1.8 (1.7–1.9)	2.6 (2.4–2.9)
Arginine	% protein	5.1 (3.2–8.8)	4.6 (4.0–6.0)	7.4 (6.8–8.1)
Phenylalanine	% protein	2.8 (2.2–4.0)	5.5 (5.2–6.5)	8.5 (7.7–9.4)
Ether extract	% DM	13.8 (6.7–22.5)	8.1 (2.0–12.0)	2.1 (2.0–2.2)
Crude fibre	% DM	1.1 (0.5–2.1)	–	6.7 (3.5–10.1)
Minerals (ash)	% DM	15.0 (5.1–29.7)	16.6 (12.0–23.3)	6.9 (6.8–7.0)
Calcium	% DM	5.1 (2.2–9.9)	36.3 (15.4–78.3)	3.9 (2.3–6.3)
Phosphorus	% DM	2.7 (1.6–5.0)	25.9 (19.0–40.4)	6.9 (5.8–8.6)
Sodium	% DM	0.6 (0.5–1.0)	10.0 (5.9–14.4)	0.1 (0.0–0.8)
Potassium	% DM	0.8 (0.4–1.8)	10.2 (5.9–14.4)	23.7(21.8–26.0)
Gross energy	MJ/kg DM	21.2 (16.2–24.9)	21.4 (19.6–23.8)	19.9 (19.8–20.0)

(Laura Gasco, et al., 2018)

"In the aqua feed space, because it is such a narrow spec of what can be used — it needs to be **concentrated**, it needs to be **low in fiber**, there are **specific amino acids that must be included** — the alternatives are really quite few," Wathne said.

http://www.startribune.com/cargill-s-quest-for-fish-food-grows-enriching-canola-in-montana-and-growing-protein-in-tank/410681245/

Challenges of fishmeal alternatives

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Table 1. The dry matter (DM) and crude protein (CP) apparent digestibility (AD) of selected feed ingredients determined for gold spot grouper in the Philippines and for humpback grouper in Indonesia.

Feed ingredient	Gold spot grouper		Humpback grouper	
	DMAD[1]	CPAD[1]	DMAD[1]	CPAD[1]
Marine product				
Fishmeal (Chilean 65% CP)	83.6 ± 3.09	98.0 ± 0.72		
Fishmeal (mixed 45% CP)	59.1 ± 1.23	82.4 ± 1.99	59.1 ± 1.23	82.4 ± 1.99
Fishmeal (sardine 65% CP)			87.2 ± 2.53	92.5 ± 1.40
Fishmeal (tuna 50% CP)	75.4 ± 3.61	76.2 ± 1.92		
Fishmeal (white 69% CP)	89.2 ± 1.69	98.6 ± 0.31		
Shrimp meal (Acetes 72% CP)	76.0 ± 4.00	95.0 ± 0.72		
Shrimp head meal (50% CP)			58.8 ± 3.33	78.0 ± 1.32
Squid meal (71% CP)	99.4 ± 0.95	94.2 ± 0.21		
Terrestrial animal product				
Blood meal (Australian ring 84% CP)				
Blood meal (oven dried 84% CP)			48.1 ± 0.85	55.2 ± 1.35
Blood meal (formic 87% CP)			67.9 ± 1.63	87.5 ± 0.55
Blood meal (propionic 84% CP)			61.7 ± 2.60	84.2 ± 0.69
Meat meal (Australian 44% CP)	60.8 ± 0.80	98.9 ± 1.32		
Meat meal (Philippine 45% CP)	77.7 ± 0.09	83.8 ± 1.66		
Meat solubles (73% CP)	99.3 ± 0.45	97.6 ± 0.08		
Poultry feather meal (67% CP)	74.3 ± 3.06	81.8 ± 2.58		
Plant product				
Corn germ meal (8% CP)	85.2 ± 2.81	82.9 ± 4.71		
Corn gluten meal (56% CP)	94.0 ± 2.03	99.5 ± 0.65		
Cowpea meal (white 24% CP)	74.2 ± 3.14	93.5 ± 1.22		
Lucaena (ipil-ipil) meal (19% CP)	56.0 ± 0.04	78.8 ± 2.64		
Lupin albus meal (26% CP)	54.1 ± 1.24	97.5 ± 3.65		
Palm oil cake meal (11% CP)			45.3 ± 2.37	80.5 ± 1.30
Rice bran meal (11–14% CP)	68.5 ± 7.02	42.7 ± 5.38	22.2 ± 1.52	59.5 ± 1.41
Soybean concentrate (54% CP)	76.3 ± 4.88	85.5 ± 0.40		
Soybean meal (full-fat 41% CP)			54.8 ± 2.72	67.2 ± 1.29
Soybean meal (solvent 51% CP)	75.7 ± 1.69	96.0 ± 0.13		
Wheat flour (9% CP)	72.8 ± 0.85	82.9 ± 1.26		

[1] Mean ± SD.

From: Advances in Grouper Acquaculture. Edited by M.A. Rimmer, S. McBride and K.C. Williams

Challenges of fishmeal alternatives

High-quality fishmeal

Made up of single fish species

High protein level (minimum 65% protein)

High freshness

High digestibility

Low contaminants (heavy metals, etc.)

EXPERIMENTAL FISH MEAL COMPOSITION (AS FED)			
	Fresh	Moderately Fresh	Stale
Moisture (%)	7.8	9.3	9.7
Ash (%)	11.3	11.4	10.7
Crude fat (%)	8.3	7.8	9.8
Crude protein (%)	66.9	64.8	63.0
TVN (mg N/100g of raw material)	14	30	50
Histamine (ppm)	28	1850	4701
Cadaverine (ppm)	51	803	1599
Putrescine (ppm)	35	446	916
Tyramine (ppm)	-	285	657
Digestibility in mink (%)	91.4	89.7	89.8

EFFECT OF RAW MATERIAL FRESHNESS – ANCHOVY MEAL

GROWTH OF SHRIMP

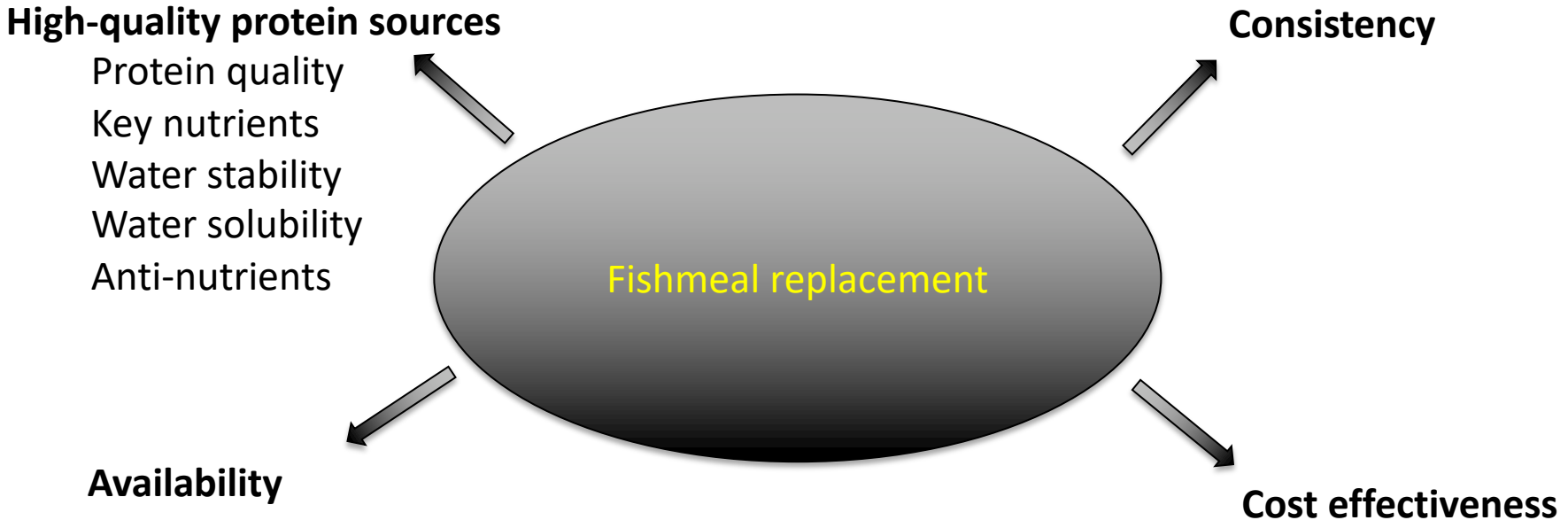
	FRESH (F)	MOD FRESH (MF)	STALE (S)	Significance
		Nuevo Leon	P.vannemi	
Trial 1 15 days	0.59	0.50	0.47	F>MF&S*
Trial 2 28 days	1.92	1.64	1.63	G>MF&S*
		Tahiti	P. monodon	
Trial 1 30 days	3.3	3.1	2.8	F>S*
		Tahiti	P.stylirostris	
Trial 1 31 days	6.7	6.0	5.6	F>MF&S*

*Sign P = 0.05

Poor performance related to low protein and digestibility in fishmeal (Divakaran and Ostrowski, 2003)

(Ricque-Marie et al., 1998)

Challenges of fishmeal alternatives



Challenges of fishmeal alternatives

Insect meal

Spray blood meal

Plasma meal

Hydrolyzed feather meal

Hydrolyzed soy protein concentrates

Fermented soy protein concentrates

Bacterial meal

Yeast meal

Algae meal

Corn protein concentrates

Fermented Corn protein concentrates

??????

1. High-quality protein sources
2. Attractant
3. Palatability
4. Cholesterol, Taurine
5. Phospholipid/Fatty acids (EPA/DHA/ARA)
6. No fiber/carbohydrates
7. No anti-nutrients
8. Safety, consistency & availability

The best is a combination of different protein sources with adding of the missing key nutrients and attractants

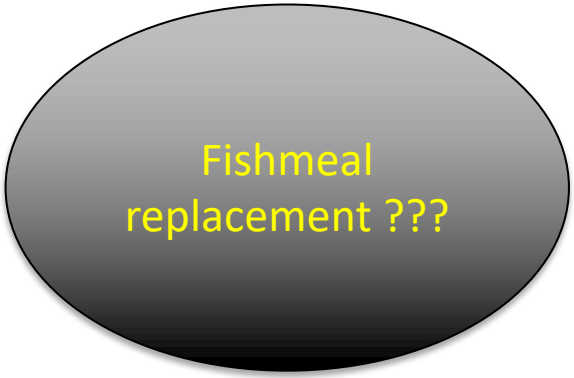
Formulation approaches for fishmeal replacement

Combination of different protein sources for better balancing the nutrients & avoiding negative impacts of antinutrients

Adding Cholesterol/Phospholipids

Adding more minerals, especially Ca/P/Na from MCP/DCP/Salt

Adding more vitamins



Adding rich EPA/DHA/ARA oils

Adding the limiting L-amino acids, especially Taurine

Adding attractant & functional nutrients and/or attractant & functional ingredients

Take-home messages

1. Fishmeal alternatives need to be considered for the safety, consistency and availability before taking into account for your feed business.

2. Highly concentrated protein ingredients (the best is minimum 65% protein)

3. Combination of different high-quality protein sources is the best approach to balance nutrients and to avoid negative impacts of contaminants, especially anti-nutrients.

4. Adding Cholesterol and phospholipids in case of replacing fishmeal for shrimp feeds.

5. Adding rich EPA/DHA/ARA oils in case of replacing fishmeal in marine fish feeds.

Take-home messages

6. Adding the limiting L-amino acids, especially Taurine.

7. Adding attractants, either nutrients or ingredients or both of the attractant nutrients & ingredients.

8. Adding more minerals, especially Ca/P/Na from MCP/DCP/Salt or from the ingredients of rich minerals.

9. Adding more vitamins to support the attractant and palatability and other health functions.

10. Control on the adding ingredients and nutrients to manage cost effectiveness and negative impacts.

Thank you !

Questions

Answers